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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(31) International Patent Classification ⁶ :
G11B 7/24

A1

(11) International Publication Number: WO 99/13466

(43) International Publication Date: 18 March 1999 (18.03.99)

(21) International Application Number: PCT/US97/15911

(22) International Filing Date: 10 September 1997 (10.09.97)

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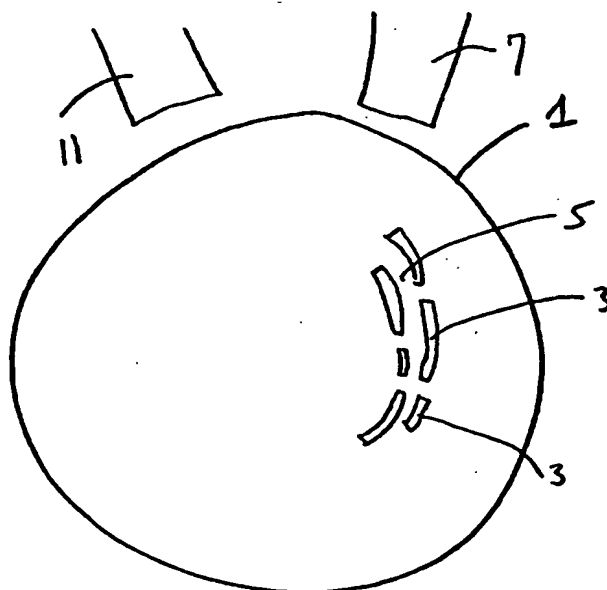
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(81) Designated States: AU, JP, SG, European patent (AT, BE, CH,
DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT,
SE).

Published

With international search report.

(54) Title: DUAL DATA RECORDED COMPACT DISC



(57) Abstract

The optical recording device including a reading head (11) and a reading laser (7) for encoding optical data (3) on a CD (1) as two dimensional (i.e. pit length and pit depths (13, 15)) optical data (3) along a spiral track, one of the data streams may be used to implement a hologram on the data recording surface, the preferred form of the invention uses a uniform pit depth within each pit, causing pit depth to vary only from pit to pit and not within a single pit, the second data stream relies on the primary data stream for much of the necessary error correction required in dense data transmission media.

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DUAL DATA RECORDED COMPACT DISCBACKGROUND OF THE INVENTION

Compact discs are typically composite objects having a series of pits impressed into a plastic surface, usually during an injection molding process. These pits and the lands between them are arranged in a spiral pattern that can be tracked by a laser beam which advances slowly along a radius while the disc is spun about an axis through the center of the disc. The pit/land surface is coated with a thin reflective metal layer. The laser beam is reflected from the metal layer coating the pits and lands and the reflection is analyzed to observe the change in reflectivity associated with a transition from a land to a pit or vice versa. To enhance the change in reflectivity the wavelength of light is chosen to cause interference between light reflected from the bottom of a pit and light reflected from a land. In common practice, the light is incident from the side that sees the pit as a bump, and the reference to light reflected from the bottom of a pit herein may be understood as light reflected from the pit seen from beneath as a bump.

The wavelength of light is not chosen arbitrarily, but is related to the depth of the pits. By detecting the change in reflectivity, the length of the pit and or land is measured. Data is encoded onto the compact disc as varying lengths of the pits and lands. The data may be analog or digital data. For example a voltage level may correspond directly to a pit length in an analog recording, or the length of the pits/lands

1 may represent strings of 0's or 1's for the recording of digi-
2 tal data.

3 The amount of data that can be encoded onto a disc is
4 limited by the density of pits and lands that can be accurate-
5 ly reproduced by the injection molding procedure and that can
6 be accurately read by the scanning laser device. Some error
7 rate can be tolerated if the data is placed on the disc in a
8 somewhat redundant format that allows errors to be sensed and
9 corrected. Thus as the pits and lands are decreased in size
10 it becomes necessary to provide greater redundancy in the data
11 until a limit is reached in the amount of data that can be
12 stored on the disc surface.

13

14

BRIEF DESCRIPTION OF THE INVENTION

15 The present invention stores two separate streams of
16 optical data on a CD as two dimensional (i.e. pit length and
17 pit depth) data along the spiral track. One of the data
18 streams corresponds to pit depth and may be used to implement
19 a hologram on the data recording surface. The preferred form
20 of the invention uses a uniform pit depth within each pit,
21 causing pit depth to vary only from pit to pit and not within
22 a single pit. The second data stream requires less error
23 correction data encoded as pit depth; it relies on the primary
24 data stream encoded as pit length for much of the necessary
25 error correction required in the compact disc.

26 The invention also comprises a novel method for manufac-
27 turing such a two dimensionally encoded compact disc and a

1 novel method for reading the data using level detectors to
2 separate the two data streams.

3 The invention relies on the unexpected discovery that it
4 is not necessary to fix pit depth at one quarter of a wave-
5 length of the reading laser in order to effectively read data
6 from a compact disc.

7 An alternative embodiment of the present invention does
8 not record a separate secondary data bit in each pit/bump but
9 rather uses a clock to record a bit in each equal time inter-
10 val corresponding to at least the largest time interval occu-
11 pied by a pit/bump under the reading head. In that case one
12 of the level detectors used to read the data is replaced by a
13 clock. This records less data than the preferred embodiment,
14 but has the advantage of simplifying the system electronics.

15

16 BRIEF DESCRIPTION OF DRAWINGS

17 Fig. 1 represents a schematic view of a CD and its
18 reading components.

19 Fig. 2 represents a cross section view of the data
20 recording surface of a CD according to the present invention.

21 Fig. 3 represents the intensity level diagram for the
22 output voltage signal at the reader head of a CD player for
23 the present invention.

24 Fig. 4 represents a schematic block diagram of the
25 algorithmic logic of the data interpreter of the present
26 invention.

27 Fig. 5 represents a diagram of the intensity level for

1 the output voltage signal showing the voltage levels trigger-
2 ing the logic of Fig. 4.

3
4 DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

5 The present invention implements an unexpected discovery
6 concerning data recorded as pits on a compact disc, namely
7 that the depth of the pits is, contrary to the published lit-
8 erature, not a critical parameter in the manufacture of such
9 discs. For purposes of this disclosure the compact discs will
10 be referred to as CDs, but it should be understood that the
11 term CD is intended to include multiple sided compact discs
12 and to the DVD format or other optical recording formats as
13 well.

14 In particular, it has been unexpectedly discovered that a
15 laser reading beam need not have a wavelength that is approxi-
16 mately 4 times the depth of a pit or bump. Indeed it has been
17 unexpectedly discovered that a wavelength approximately 2
18 times the depth of a pit or bump is most effective for reading
19 data from the compact disc. This directly contradicts the
20 simplistic view of the interference/diffraction/scattering
21 effects at the surface of the data region of a compact disc
22 and is believed to be caused by the complexity of the inter-
23 ference/diffraction of light from an irregularly pitted sur-
24 face.

25 This unexpected discovery opens up literally a new dimen-
26 sion for the storage of digital data on compact discs. Where-
27 as data has been stored one dimensionally as pit lengths along

1 a spiral track, the present invention enables one to store the
2 data two dimensionally as both pit length and pit depth along
3 the spiral track. The preferred embodiment of this invention
4 uses a uniform pit depth for each pit, causing pit depth to
5 vary only from pit to pit and not within a single pit. This
6 provides two advantages. First it enhances quality control
7 because it is possible to recognize unintended pit variation
8 when it occurs within a single pit. Second it enables the use
9 of conventional data recording equipment in the compact disc
10 recording field.

11 Figure 1 depicts a compact disc 1 or single surface of a
12 two sided disc with the data pits 3 greatly enlarged. The
13 pits are arranged in a spiral pattern with a land area 5 be-
14 tween adjacent spirals so that they may be read in sequence by
15 a reading laser 7. Figure 2 depicts a cross section of the
16 information bearing surface 9 of the compact disc, preferably
17 a metallic film capable of reflecting laser light, the film
18 being embedded in a plastic protective layer through which
19 laser light reflected from the data surface may be detected by
20 a reading head 11. The surfaces are formed with pits of vary-
21 ing depth, by a method to be described below, and the reading
22 head contains a peak detecting means that is capable of sens-
23 ing the depth of pit.

24 Figure 3 shows a typical voltage signal as a function of
25 time corresponding to the intensity of the light received in
26 the photodetector of the reading head of the compact disc
27 player. Since the disc rotates at constant linear velocity

1 under the reading head Figure 3 also shows an indication of
2 the depth of the pit along the data track. As shown in Figure
3 3, a low intensity signal 13 represents a pit having a wave-
4 length of approximately $\lambda/2$. A medium intensity signal 15
5 represents a pit having a wavelength of approximately $\lambda/4$. A
6 high intensity signal 17 represents a land area between pits
7 on the data recording surface.

8 In operation the reading head of the player senses a
9 variation of intensity of the signal reflected from the data
10 containing surface. The intensity encodes two data signals
11 that must be unfolded from each other. This is accomplished
12 by the algorithm schematically represented in Fig. 4. The
13 signal is first passed through a signal splitter and one por-
14 tion is sent to a logical analyzer 21 to perform the normal CD
15 interpretation of the pit/bump length data. The second por-
16 tion is sent to logical analyzer 23, i.e., a level detector
17 which recognizes the crossover from the land to a pit bump
18 (see point 25 in Fig.5). The level detector 23 then enables
19 the AND gate 27 and passes the signal to a high level detector
20 which causes the AND to go high only if the pit/bump depth is
21 sufficiently deep. In the preferred embodiment each pit pre-
22 sents the opportunity to encode a single secondary data bit
23 regardless of the length of the pit/bump. The logic presented
24 recognizes the termination of a single pit/bump in order to
25 provide for the situation where two identical bits occur in
26 succession.

27 An alternative embodiment of the present invention does

1 not record a separate secondary data bit in each pit/bump but
2 rather uses a clock to record a bit in each equal time inter-
3 val corresponding to the largest time interval occupied by a
4 pit/bump under the reading head. In that case the first level
5 detector is simply replaced by a clock. This has the disad-
6 vantage of recording less data, but the advantage of simpli-
7 fying the system by eliminating the need to continuously
8 locate the edge of a pit/bump.

9 One advantage of the present invention is that it is not
10 necessary to provide error correction in as much detail for
11 the secondary data as for the primary data, because the pri-
12 mary data can contain such information as is necessary to
13 locate the origin of a data word in the event that foreign
14 particles obscure the data. In effect, checksum data or its
15 equivalent which is provided in the primary data will show
16 when reading errors have become excessive and the reading head
17 can assume that such errors are not affecting the secondary
18 data if they have not affected the primary data. This piggy-
19 back effect, is not to my knowledge implemented in any other
20 form of data communication.

21 The process for manufacturing a disc according the
22 present invention is as follows:

23 The normal manufacturing process for a CD is altered by
24 taking the normal laser writing signal that is modulated in an
25 on/off manner to encode the pits and further modulating the
26 intensity of the laser to create different exposure levels in
27 the photoresist or in the non-photoresist coating on a glass

1 master. In an ablative process the same variation in laser
2 intensity is performed. Typical wavelengths for the reading
3 light are 780 nm for CD's and 650 nm for DVD's.

4 One use for the present invention is to superpose a
5 hologram onto the data portion of the data recording surface
6 of a CD. This is accomplished by taking a conventional holo-
7 gram from a surface where one is impressed in plastic and re-
8 cording the height of each pixel element and expressing that
9 data in a digital form for recording on the surface of a CD.
10 This causes a slight distortion of the hologram since the pre-
11 sent invention is restricted to pixels that correspond in
12 dimension to the length of the available pits. It has unex-
13 pectedly been discovered, however, that in view of the small
14 size of the pits/bumps on the surface a conventional hologram,
15 that this slight distortion is not a significant detriment to
16 the operation of this method. This effect is minimized in the
17 embodiment where a clock is used to define the pixel size
18 rather than relying on the individual pit/bump length.

1 WHAT IS CLAIMED IS:

2 1. A disc medium for the optical recording first and
3 second digital data for readout by a laser having a wavelength
4 λ comprising

5 a series of pits arranged in a spiral pattern in a
6 reflective material having

7 a predetermined plurality of lengths encoding first
8 digital data and

9 a separate predetermined plurality of pit depths
10 encoding second digital data,

11 wherein said plurality of pit depths comprises at
12 least the depths $\lambda/2$ and $\lambda/4$.

13 2. The disc medium for optical recording of claim 1
14 wherein said second digital data comprises a bit pattern which
15 when implemented in variable pit depths forms a hologram
16 observable through a transparent surface of said disc medium.

17 3. The disc medium for optical recording of claim 1
18 wherein said second digital data comprises a bit pattern which
19 when implemented in variable pit depths forms a security
20 encoded area on said disc.

21 4. The disc medium for the optical recording of claim 1
22 wherein the second digital data is encoded by a pit of greater
23 depth ($\lambda/2$) representing a digital 1 and a pit of lesser depth
24 ($\lambda/4$) representing a digital 0 or vice versa.

25 5. The disc medium for the optical recording of claim 1
26 wherein the second digital is encoded by a transition from a
27 pit of greater depth ($\lambda/2$) to a pit of lesser depth ($\lambda/4$)

1 representing a digital 1 and the absence of such a transition
2 representing a digital 0, or vice versa.

3 6. The disc medium for the optical recording of claim 1
4 wherein said pit depths include $n-2$ additional depths and each
5 such pit depth represents a digit in a base n system, wherein
6 the density of data represented by said pit depths is enhanced
7 by a factor of $(n/2)^x$ where x is the word length.

8 7. A system for reading dual digital data from a com-
9 pact disc having data pits with variable length and variable
10 pit depth comprising
11 peak detector means for detecting the depth of a
12 pit.

13 8. A method for separating two data signals from a CD
14 having variable pit/bump length and pit/bump depth, comprising

15
16 sensing a variation of intensity of a signal
17 reflected from a data containing surface, wherein the
18 intensity encodes two data signals, that must be unfolded from
19 each other,

20 splitting the signal and sending one portion to a
21 logical analyzer,

22 performing the normal CD interpretation of the
23 pit/bump length data,

24 sending a second portion of the signal to a second
25 logical analyzer comprising a level detector,

26 recognizing the crossover from the land to a pit
27 bump

1 implementing logical circuitry to determine whether
2 the pit/bump depth is sufficiently deep.

3 9. A method for separating two data signals from a CD
4 having variable pit/bump length and pit/bump depth, comprising
5 sensing a variation of intensity of a signal
6 reflected from a data containing surface, wherein the
7 intensity encodes two data signals, that must be unfolded from
8 each other,

9 splitting the signal and sending one portion to a
10 logical analyzer,

11 performing the normal CD interpretation of the
12 pit/bump length data,

13 sending a second portion of the signal to a second
14 logical analyzer comprising a level detector,

15 clocking a signal to indicate the start of a new
16 depth encoded data bit,

17 implementing logical circuitry to determine whether
18 the pit/bump depth is sufficiently deep.

19 10. A disc medium for the optical recording first and
20 second digital data for readout by a laser having a wavelength
21 λ comprising

22 a series of pits arranged in a spiral pattern in a
23 reflective material having

24 a predetermined plurality of lengths encoding first
25 digital data and

26 a separate predetermined plurality of pit depths
27 encoding second digital data,

1 wherein said plurality of pit depths comprises at
2 least two different predetermined pit depths.

3

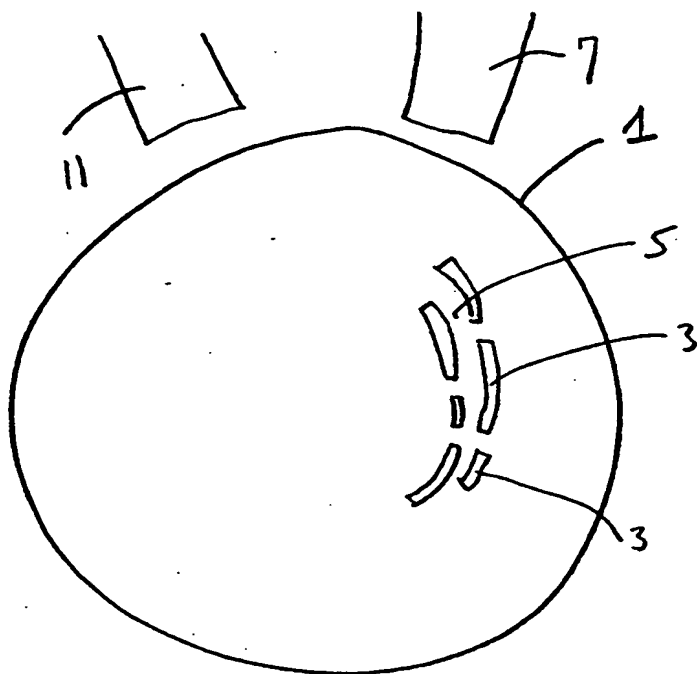


Fig. 1



Fig. 2

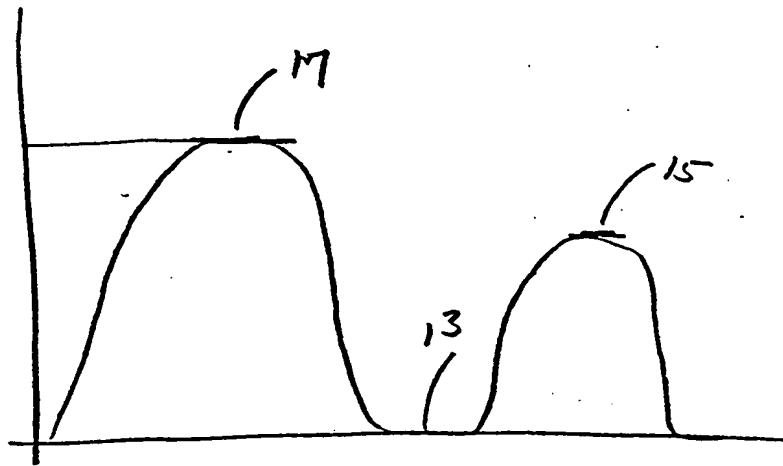


Fig 3

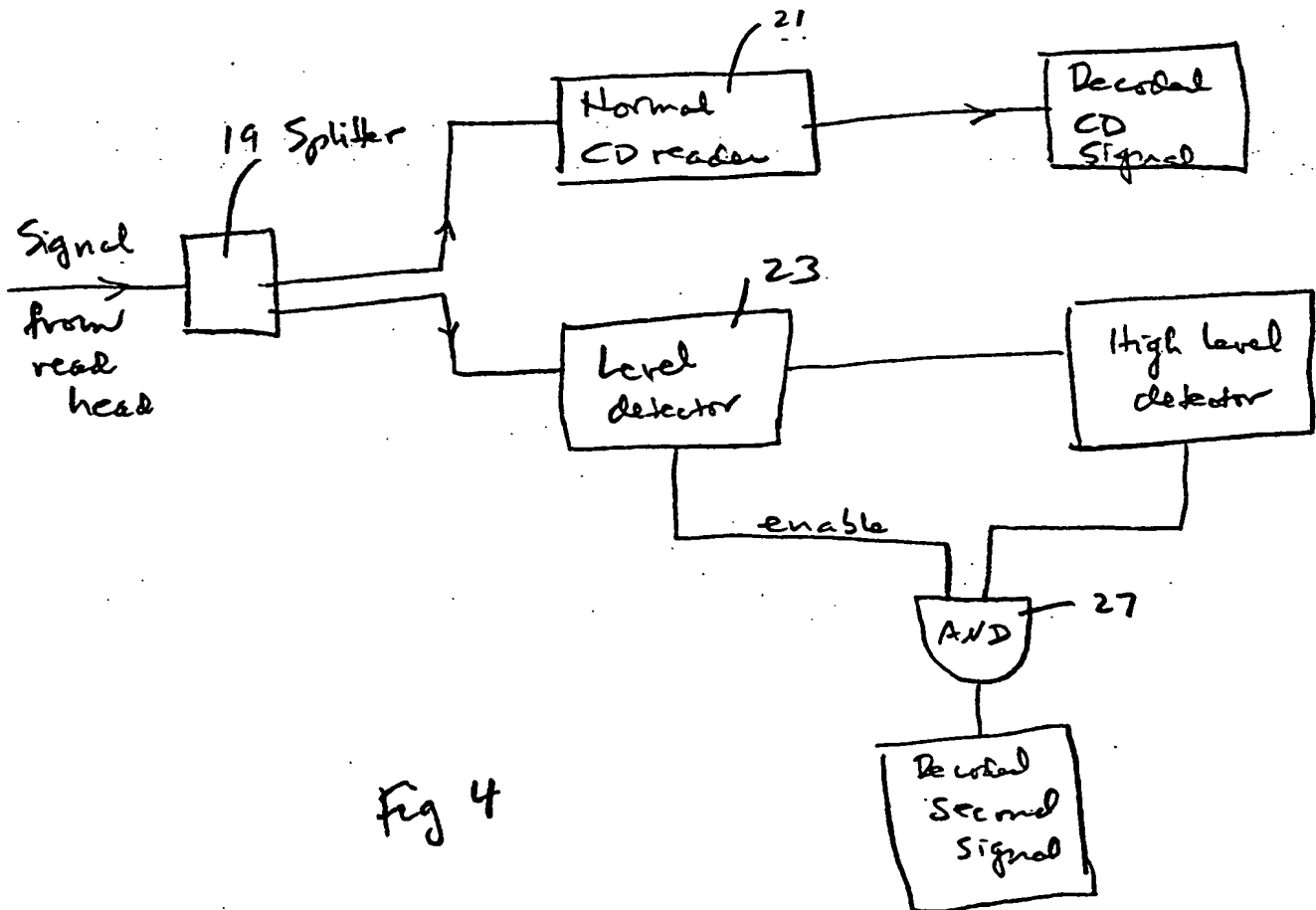


Fig 4

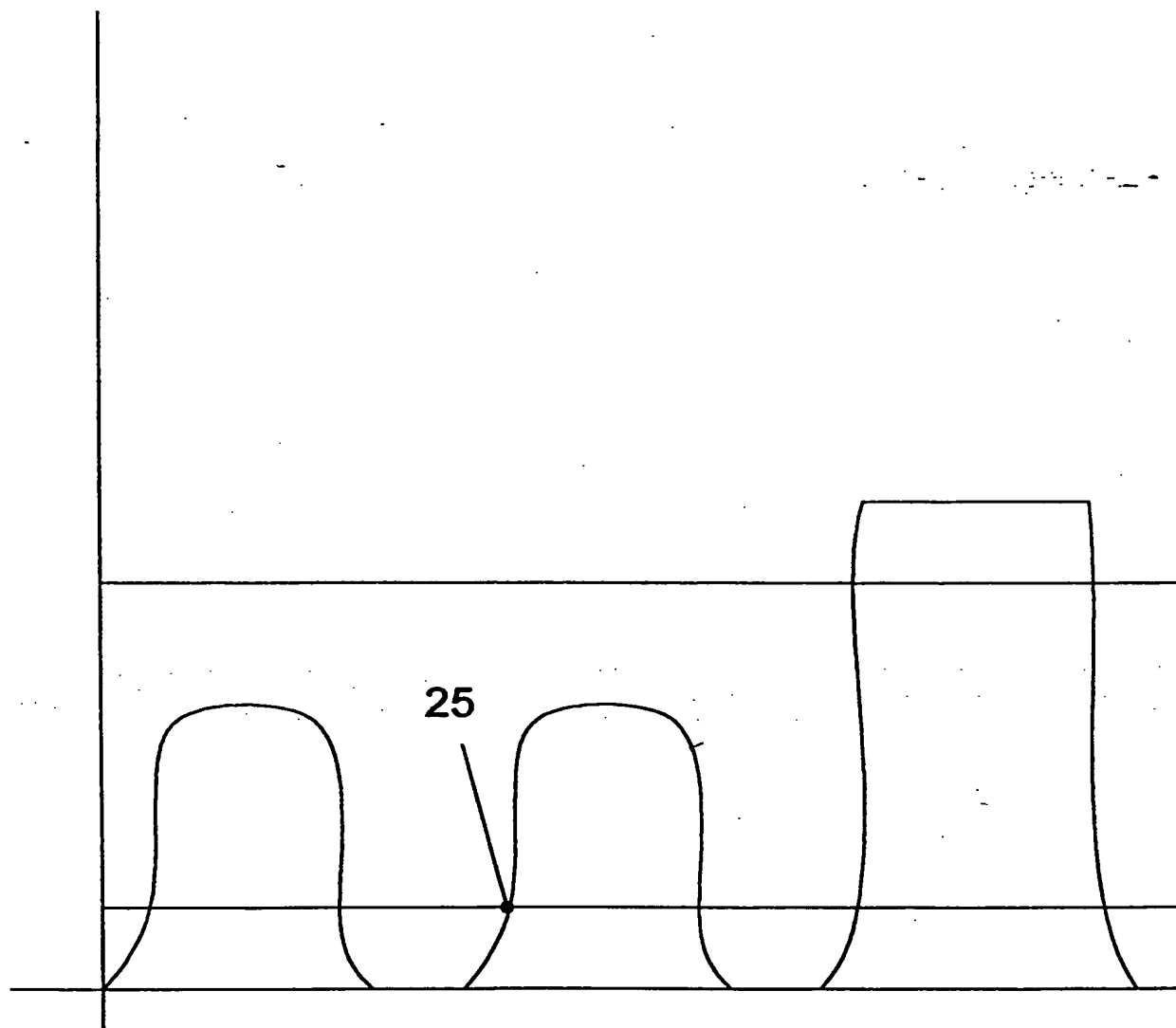


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/15911**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(6) :G11B 7/24

US CL :369/275.4, 275.1

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 369/275.4, 275.1, 275.3, 109, 103

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

A.P.S

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,577,016 A (INAGAKI et al) 19 November 1996 (19-11-96), figure 1; column 16, lines 10-56; column 18, lines 56-61.	1-5,10
X	US 5,559,787 A (NOMOTO) 24 September 1996 (24-09-96), figure 4A; column 3, line 22 to column 4, line 51; column 5, lines 25-52.	1-5,10
A	US 5,471,455 A (JABR) 28 November 1995 (28-11-95), whole document.	None
A	US 5,453,969 A (PSALTIS et al) 26 September 1995 (26-09-95), whole document.	None

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
A document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
E earlier document published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
L document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"A" document member of the same patent family
O document referring to an oral disclosure, use, exhibition or other means	
P document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

14 OCTOBER 1997

Date of mailing of the international search report

24 OCT 1997

Name and mailing address of the ISA/US
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/15911

Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Extra Sheet.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-6,10

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/15911

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING

This ISA found multiple inventions as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid. The groups are as follows:

Group I, claim(s) 1-6 and 10, drawn to an optical disk.

Group II, claim(s) 7, drawn to peak detector.

Group III, claim(s) 8 and 9, drawn to a method for separating two data signals from a CD.

The inventions listed as Groups I, II and III do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

The claims of groups I, II and III are differed in structures/arrangement/combinations during storing information data, for example, the invention of group I is directed to an optical recording medium in general for storing information data, the invention of group II is directed to a peak detector circuit for detecting the depth of the recorded pits, and the invention of group III is seem usefull for separating two data signals from a CD.